State of California
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INTERIM REPORT
SP-F10, TASK 2B

Oroville Facilities Relicensing
FERC Project No. 2100

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INTERIM REPORT
SP-F10, TASK 2B
STEELHEAD SPAWNING METHODS

Oroville Facilities Relicensing
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1.0 SUMMARY

The objective of this literature review and evaluation is to identify opportunities for improvement in a method to quantify steelhead spawning in the Feather River. A review was conducted of available literature describing devices and methods that could be used to enumerate migrating or spawning salmonids to fulfill the requirements of Task 2B of SP-F10. A brief description of the survey type, advantages and disadvantages compared to other survey methods, examples of each survey method's previous uses, and a brief statement of applicability to the Feather River were presented. Additionally, because DWR has already begun surveying for steelhead in the Feather River a brief description of the surveys completed to date was also presented. The results of the steelhead spawning survey methodologies and alternatives confirms the conclusions of the preliminary investigation conducted in the study plan development and in the definition of the steelhead spawning survey associated with Task 2B of SP-F10. Potential survey methods for spawning steelhead combined with consideration of the physical characteristics of the Feather River reveal that a combination of methods including bank, snorkel, and boat surveys are best suited for surveying spawning steelhead in the Feather River.

2.0 PURPOSE

The purpose of this portion of Task 2B of SP-F10 is to conduct a literature review to summarize and evaluate potential methodologies for observing and measuring steelhead spawning. On March 19, 1998, naturally-spawned Central Valley steelhead (*O. mykiss*) were listed as threatened under the federal Endangered Species Act (ESA) by the National Marine Fisheries Service (NMFS) (NMFS 1998). The Central Valley Evolutionarily Significant Unit (ESU) includes all naturally-spawned populations of steelhead (and their progeny) in the Sacramento and San Joaquin rivers and their tributaries, which includes the naturally-spawned steelhead in the Feather River (NMFS 1998). In order to evaluate potential relationships between project operations and ESA-listed steelhead, it is desirable to collect data regarding steelhead spawning locations and relative abundance of spawning steelhead. This portion of Task 2B of SP-F10 is a literature review designed to evaluate the types of methods that could be used to survey spawning steelhead and the applicability of each method to the Feather River.

In addition to the ESA, Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife, and botanical resources in the vicinity of the project (Code of Federal Regulations 2001). The discussion is required to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact from on-going and future operations. As a subtask of Study Plan (SP) F-10, *Evaluation of Project Effects on Salmonids and their Habitat in the Feather River Below the Fish Barrier Dam*, Task 2B fulfills a portion of the FERC application requirements by providing a literature review that summarizes and evaluates potential methods of surveying spawning steelhead.

Ongoing operation of the Oroville facilities affects flows, water temperatures, and supply of gravel that, in turn, may affect spawning, incubation and initial rearing of salmonids. Flow, water temperature, and gravel quality are important factors influencing the spawning, incubation and initial rearing lifestages of salmonids. Task 2 of SP-F10 will evaluate project effects on the spawning, incubation and initial rearing period of salmonids in the Feather River. Task 2A evaluates spawning and incubation substrate availability and suitability for salmonids in the Feather River. Task 2B consists of several components, with the overall objective of evaluating the timing, magnitude and frequency of flows on salmonid spawning distribution. Task 2C evaluates the timing, magnitude and frequency of water temperatures and their effects on the distribution of salmonid spawning and on egg and alevin survival, while Task 2D evaluates flow fluctuation-related effects on redd dewatering. For further description of Tasks 2A, 2C, or 2D relating to spawning, incubation, and initial rearing salmonid lifestages, see SP-F10 and associated interim and final reports.

3.0 BACKGROUND

3.1 STUDY AREA

The study area in which the results of the literature review could be applied includes the reach of the Feather River extending from the Fish Barrier Dam to the confluence with the Yuba River. This is the geographic range within the Feather River that encompasses areas in which Feather River steelhead may spawn (DWR 2002a). The literature review compiled literature regarding advantages and disadvantages and case studies utilizing a variety of survey methods from rivers located throughout a wide geographic range of North America. Literature from California rivers was utilized to the extent possible.

3.2 EXISTING INFORMATION REGARDING FEATHER RIVER STEELHEAD SPAWNING

Currently, little is known about the relative abundance of in-river steelhead spawners in the Feather River. Aside from counts made during project construction, no data are available regarding escapement of naturally spawning steelhead in the Feather River (DWR 2001). There are several reasons that relatively little information regarding steelhead spawning is available in comparison to information regarding other salmonids such as Chinook salmon.

For most rivers and streams of the Sacramento River basin, detailed information on steelhead spawning sites and abundance is poor because steelhead life-history traits have hampered steelhead monitoring and research (McEwan 2001). Adults tend to migrate during high flow periods, making them difficult to observe (McEwan 2001). Steelhead redds are difficult to observe because steelhead spawn at higher flows than do Chinook salmon (McEwan 2001). Steelhead redds are generally indistinguishable from Chinook salmon redds in the Feather River due to the superimposition resulting from heavy utilization of spawning riffles by both Chinook salmon and steelhead, and because water clarity is generally poor during the winter months when steelhead spawning occurs, observation of spawning steelhead can be difficult (DWR et al. 2000). Additionally, maintaining counting weirs and other monitoring equipment and structures during these higher flow periods can be challenging (McEwan 2001). Because steelhead do not necessarily die after spawning, documentation of spawning location cannot be definitively achieved through carcass surveys and traditional escapement estimates cannot be used to estimate abundance (DWR 2001). Therefore, although carcass surveys are a reliable method to estimate Chinook salmon spawning escapement, they are not applicable to steelhead because many adults survive spawning and most adults that do not survive do not die on the spawning grounds.

In addition to biological characteristics that contribute to difficulties in monitoring steelhead spawning, there is a general lack of established monitoring and evaluation programs regarding steelhead spawning in Central Valley rivers. For example, in a review of monitoring and research efforts on steelhead in the Central Valley conducted by the Interagency Ecological Program's Steelhead Project Work Team, forty existing monitoring and research projects were identified and their objectives summarized (Interagency Ecological Program Steelhead Project Workteam 1999). Of these forty projects, none specifically listed obtaining information regarding distribution and abundance of steelhead spawners in the program objectives. While some incidental information regarding steelhead spawning may result from Chinook salmon carcass surveys, the project descriptions suggested that assessment of steelhead spawning was not a specific focus of any of the projects reviewed. Despite the current lack of established comprehensive steelhead spawner assessment programs, the Steelhead Project Work Team specifically recommended that investigations to define the location and timing of steelhead spawning, as well as the number of steelhead spawners, be included in the basic monitoring approach for Central Valley steelhead. A number of projects reviewed were focused on steelhead, but focus primarily on juvenile emigration and habitat utilization, with none specifically designed to monitor steelhead spawning.

Although there are many biological characteristics that contribute to difficulties in monitoring steelhead spawning, some information exists regarding steelhead spawning in the Feather River. The enumeration program for adult steelhead is less extensive than the enumeration program for adult Chinook salmon spawners. Steelhead escapement in the Feather River can be split into two components: adult steelhead entering the Feather River Fish Hatchery and in-channel adult steelhead spawners. Beginning in 1967, when formal operation of the hatchery began, the number of adult steelhead spawners arriving at the Feather River Fish Hatchery was recorded and are expressed as total counts of individual adult steelhead climbing the fish ladder and entering the hatchery each year to spawn. Although data continue to be collected and constitute a relatively lengthy period of record, data describing the number of steelhead spawners entering the Feather River Fish Hatchery do not provide information regarding the location or number of in-river spawning steelhead. Because there is no quantitative information available to describe the number of in-channel adult steelhead spawners, it is not possible to assess whether the adult steelhead returns to the Feather River Hatchery are representative of the total number of adult steelhead spawning in the Feather River. It has been reported that most steelhead spawn in the hatchery, although some spawn in the Feather River (DWR et al. 2000).

As described above and as with other Central Valley rivers, there is very little information regarding Feather River steelhead spawning sites and abundance coming from carcass or redd surveys. However, some information regarding the distribution of spawning steelhead in the Feather River can be inferred from observations collected during the snorkel surveys performed by DWR from March through August in 1999, 2000 and 2001. From 1999 to 2001, almost all of the steelhead spawning activity appears to have been concentrated between the Fish Barrier Dam and the Thermalito Afterbay Outlet. In fact, in 1999, 2000, and 2001, 91%, 77% and 84% of all the young-of-the-year (i.e., juveniles with fork lengths smaller than 100 mm) steelhead observations during the snorkel surveys occurred in the upper mile of the reach extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet. In each of the 3 years surveyed, less than 1% of the observed young-of-the-year (YOY) steelhead were observed downstream of the Thermalito Afterbay Outlet (DWR 2002b). Additionally, some steelhead have been observed spawning in the small secondary channels of the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet, where substrate size is smaller and cover is greater than in the main river, thereby providing a suitable area for spawning (DWR 2001). Thus, current knowledge regarding steelhead-spawning distribution suggests that most of the steelhead spawning activity appears to be concentrated between the Fish Barrier Dam and the Thermalito Afterbay Outlet, and specifically in the upper section of this reach.

Although quantitative information is not available regarding the temporal distribution of steelhead spawners, observations by fishery biologists during carcass surveys and other field studies provide some information regarding the timing of steelhead spawning in the Feather River. Steelhead are present in the Feather River from September through April, with peak immigration probably occurring during September through January (DWR et al. 2000). In the Feather River, steelhead spawning occurs from December through April (DWR 2002a) and occurs primarily at the upstream portion of the reach extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet (DWR 2002b). Currently, the length of time adult steelhead reside in the Feather River after spawning and the post-spawning mortality of Feather River steelhead is unknown (DWR 2001).

In order to provide additional information regarding the distribution and relative abundance of steelhead spawners in the Feather River, targeted surveys regarding in-channel adult steelhead spawning are being conducted for the Oroville Facilities relicensing process (DWR 2002a). The surveys conducted during the 2002-2003 steelhead spawning season included a steelhead redd survey and an adult steelhead abundance boat survey.

3.2.1 Redd Surveys

The steelhead redd survey was intended to more accurately quantify the number of redds present in the Feather River. The redd surveys were conducted at transect sites which were selected based on previous snorkel survey information regarding locations of YOY steelhead. Therefore, these locations represent the areas in which observation of spawning steelhead are most likely, providing the best chance to gain information on the physical attributes (size, substrate composition, etc.) of steelhead redds in the Feather River. A total of 41 riffle/glide transects were selected, with 23 transects in the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet and 18 in the reach of the Feather River extending from the Thermalito Afterbay Outlet to Honcut Creek (pers. com., J. Kindopp, DWR, 2003b). Each transect was predetermined and marked on field maps. The transect line shown on the map was the center of the transect, which was approximately 30 meters long and 30 meters wide. Sampling each transect involved wading the entire transect looking for steelhead or signs of steelhead spawning (redds). A boat was used to observe redds and fish when possible, but most transects were in shallow water, precluding the use of boats. In these cases, two to three people waded the transect area looking for steelhead and/or steelhead redds. In transects or locations where many redds were observed, small washers with blue flagging were placed on individual redds to avoid counting the same redd twice (pers. com., J. Kindopp, DWR, 2003a).

The following table describes the type of data collected each time a steelhead redd was observed.

Table 3.2-1. Steelhead redd survey form

Survey Type	Transect or Roving
Steelhead Present/How Many	Yes No
Riffle Position (of redd)	Head Middle Tail
Redd distance from bank	(m)
GPS Coordinates	N
	W
Overhead Cover (*circle all that apply*)	1 2 3 NO
Instream Cover (*no more than 2*)	B C E F NO
Substrate Code (*no more than 2*)	1 2 3 4 5 6
Channel Geomorphic Unit	R G P W
Water Depth at front of redd	(m)
Water Velocity at front of redd	(ft/s)
Redd Length	(m)
Redd Width	(m)

3.2.2 Adult Steelhead Abundance Boat Surveys

The adult steelhead abundance boat surveys (i.e., roving surveys) were intended to sample most of the spawning habitat (riffles/glides) from the Fish Barrier Dam to Honcut Creek. Pools previously defined on habitat maps were not sampled. Roving surveys were conducted during travel between transect sites sampled during the steelhead redd survey. The adult steelhead abundance boat surveys were performed in a method similar to the Feather River escapement survey. The crew drifted a boat through and around spawning areas looking for steelhead and/or steelhead redds. Each of the roving areas was marked on the steelhead redd maps with clear numbered boundaries. If a redd was spotted in a roving area, the same physical data collected for transect redds was collected. Data describing the number and location of observed spawning steelhead were also recorded during this survey. Any steelhead carcasses found were processed in the following manner. Fork length, sex (if possible), location, life stage and life history (adipose fin clipped or not) data were collected. If the fish was adipose fin clipped, the head was removed and a standard CWT head tag label was attached. If the steelhead had not had its adipose fin previously clipped, the head was removed and placed in a bag with an appropriate label. All heads were returned to the DWR Oroville Field Division for storage. Also, a large (2 cm x 2 cm) piece of the caudal fin was removed for genetic analysis. Tissue samples were sent to the CDFG tissue archive in Sacramento (pers. com., J. Kindopp, DWR, 2003a). The information collected in the redd survey and boat survey is expected to increase our current level of knowledge with regards to the location of steelhead spawning and the relative abundance of steelhead spawners.

4.0 METHODOLOGY

4.1 LITERATURE REVIEW

A literature review of steelhead spawning survey method was conducted to supplement the preliminary investigation of survey methods and alternatives that was conducted during development of the steelhead spawning surveys described in Task 2B of SP-F10. In addition to descriptions of potential survey methods, the literature review compiled literature regarding advantages and disadvantages of each survey method and case studies from rivers located throughout a wide geographic range of North America. Literature from California rivers was utilized to the extent possible. Initial review of the literature revealed a paucity of information on steelhead spawning survey methods while a surplus of information was available on Chinook salmon spawning survey methods including redd surveys, direct observation of spawning activity, and carcass surveys.

Information was collected regarding spawning surveys for multiple salmonid species as well as methods of enumerating spawning salmon and steelhead. Information regarding survey methods for species other than steelhead was gathered in order to make use of the widest search parameters possible. This allowed identification and analysis of all possible survey methods, not only those utilized in the past for steelhead spawning surveys. Additionally, due to the elusive nature of steelhead and the inherent difficulty in enumerating iteroparous anadromous spawning fish, steelhead enumeration survey methods were also examined. Analysis of both spawning survey methods and enumeration methods for multiple salmonid species allowed evaluation of all possible steelhead spawning survey methods.

After initial review of all available literature covering all possible spawning survey methods, boat surveys, snorkel surveys, bankside count surveys, and stationary video surveys were selected for further analysis. Aerial surveys, hydroacoustic surveys, mark-recapture surveys, electrofishing surveys, and use of stationary fishing gears, such as various types of nets and weirs were immediately discarded from further analysis for reasons described in detail below. An extensive literature review of the four survey methods chosen for further analysis was based on the ability of the survey method to obtain information describing the location and relative abundance of steelhead spawners, the applicability of the method to the Feather River, and the ability to maintain continuity and consistency with previously collected data sets.

4.2 SURVEY METHODS NOT SELECTED FOR FURTHER EVALUATION

As stated above, aerial surveys, hydroacoustic surveys, mark recapture surveys, electrofishing surveys, and use of fishing gears were not selected for further analyses for a variety of reasons. Aerial surveys were not selected for further analysis due to the difficulty of redd and species identification from aerial photographs in the Feather River. In general, the scale at which aerial redd surveys are performed allow for redd identification in rivers such as the Feather River, but do not allow analysts to identify the species of fish that dug the redds. Additionally, because of the heavy utilization of the riffle habitat in the Feather River by spawning Chinook salmon and steelhead, superimposition of redds generally results in the inability to distinguish individual redds from aerial photography. In the Feather River, aerial redd surveys have proven unreliable in the past for the purpose of enumerating redds (DWR 2002a). For these reasons and other reasons detailed in Task 2B of SP-F10 (DWR 2002a), aerial redd surveys were not included for further analysis.

Hydroacoustic surveys were not selected for further evaluation for several reasons. Difficulty identifying a single target species among several species has been reported to be a problem in other studies utilizing this method (Hilborn et al. 1992; Thorne 1979). In order to ensure proper species identification, the proportion of the target species in the sonar beam can be predetermined based on visual surveys (Hilborn et al. 1992). Additionally, sonar beam strength requires calibration based on the expected density of individuals passing through the survey area in order to effectively determine actual target acquisition versus non-target artifacts (Hilborn et al. 1992). In addition, it has been reported that at high species densities, hydroacoustic surveys underestimate the abundance of fish (Enzenhofer et al. 1998). The high densities of Chinook salmon and steelhead that can occur in spawning areas in the Feather River may result in lengthy and potentially difficult calibration efforts in order to validate the hydroacoustic survey output with respect to species composition and enumeration. Additionally, while properly calibrated hydroacoustic surveys could provide information regarding the presence and relative abundance of steelhead, hydroacoustic surveys do not provide the opportunity to observe steelhead spawning. Although steelhead may be present in many locations, hydroacoustic surveys would not allow differentiation of a holding steelhead as compared to a spawning steelhead. Therefore information regarding the location of spawning steelhead and the timing of spawning would not be easily obtained through hydroacoustic surveys. For these reasons, hydroacoustic surveys were determined to be impractical for enumerating spawning steelhead in the Feather River and were not considered for further evaluation.

Mark-recapture surveys were not considered for further evaluation due to the limited ability of the survey protocol to answer the questions posed by SP-F10 Task 2B. Although mark-recapture surveys would effectively provide data on numbers of adult steelhead and potentially would provide information regarding post-spawning mortality, mark-recapture surveys would only provide limited information characterizing the spatial and temporal distribution of steelhead spawning. Because steelhead do not necessarily die after spawning, the location of capture or recapture may not necessarily be indicative of spawning location. The handling associated with catching, marking and releasing steelhead may also interfere with spawning activities or spawning success. Because mark-recapture does not necessarily include observations of spawning behavior, this method would be of relatively little utility with regards to determining the location and timing of spawning. As a result, mark-recapture methods were not included for further evaluation.

Electrofishing surveys to elucidate spawning locations were not chosen for further evaluation because the nature of the activity could potentially significantly interfere with spawning success. In addition, visual surveys have been effectively used as an alternative to removing listed species during enumeration surveys (Nielsen 1998).

Finally, the use of angling gears such as weirs were not considered for further evaluation. These survey methods were not analyzed because they can not be easily modified to determine spawning locations of steelhead. Weirs are generally placed in rivers and streams for determining numbers of migrating fish (Faurot et al. 2002; USFWS Fairbanks Fishery Resources Office 2001). Although the use of weirs provides surveyors with many methods of counting fish including the use of acoustic and video equipment (Enzenhofer et al. 1998; Faurot et al. 2002), their design and placement in potential spawning areas can potentially interfere with spawning activities. In addition, to determine the general location and relative abundance of spawning fish, multiple weirs would be needed at many locations throughout the river. Given the width and flow regime in the Feather River and the inability of weirs or other angling gears to specifically provide information regarding the timing and location of steelhead spawning, these methodologies were not considered for further evaluation.

4.3 SURVEY METHODS SELECTED FOR FURTHER EVALUATION

Upon initial examination of the available literature, boat surveys, snorkel surveys, bankside counts and fixed video surveys were chosen for further evaluation. These methods could be implemented with a high degree of accuracy to directly answer the questions of where and when steelhead spawn in the Feather River. Two types of boat surveys and bankside counts are reviewed and analyzed. Advantages and disadvantages for each survey method are provided. Examples from California streams and rivers are presented where information is available.

5.0 RESULTS AND DISCUSSION

5.1 BOAT SURVEYS

5.1.1 Visual Surveys

5.1.1.1 Description:

Boat surveys are generally conducted on larger river reaches including mainstem rivers that generally have higher flows (Riggers et al. 1999). Surveys are accomplished by drifting downstream in reaches where spawning is thought to occur and visually identifying spawning individuals or redds. Surveyors generally increase the likelihood of spotting individual fish or redds by wearing polarized sunglasses and hats that help reduce glare.

5.1.1.2 Advantages

- Boat survey methodology is straightforward and can be readily utilized without significant amounts of training regarding equipment and analysis techniques (Susac et al. 1999).
- Boat surveys can be used to complement other survey types with minimal additional expense (Susac et al. 1999).
- Boat surveys can cover a wide survey area (Dauble et al. 1999).
- Boat surveys can be performed in most conditions including those that are dangerous for individuals to be in the water (Dauble et al. 1999; Susac et al. 1999).

5.1.1.3 Disadvantages

- Spawning steelhead spend a limited amount of time on redds making direct observation time critical.
- Non-spawning fish tend to be elusive (Susac et al. 1999).
- It is difficult to determine observer efficiency without the use of video (Gallagher 2000).
- It is difficult to observe spawning fish when water is turbid or when flows are high (Riggers et al. 1999).
- Boats may not be able to get within close proximity to spawning fish (Interagency Ecological Program Steelhead Project Workteam 1999).
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5.1.1.4 Example applications

Multiple studies have shown that boat surveys in conjunction with other types of surveys can be relatively efficient in determining the number and location of spawning steelhead and Chinook salmon (Gallagher 2000; Riggers et al. 1999; Susac et al. 1999). Steelhead spawning surveys were conducted in 21 different watersheds or subbasins of coastal streams in Oregon from mid-January to mid-May in 1998. Larger streams were floated using a 13-foot inflatable raft. Surveyors recorded visual observations of live fish. Polarized sunglasses and baseball style hats were worn to aid in reducing glare and to protect observers eyes from overhanging vegetation. Surveyors attempted to visually determine whether or not steelhead were adipose fin-clipped. The activity of live fish observed was also noted as to whether adults were mostly holding in pools, migrating through survey area, actively spawning, or mostly spawned out (Susac et al. 1999).

In another study performed on the Noyo River in California, Gallagher (2000) employed a combination of methods including bankside surveys, boat surveys, and snorkeling surveys. Spawning surveys were conducted to quantitatively estimate steelhead populations. The surveys were intended as the recapture portion of a mark-recapture study to estimate adult population (Gallagher 2000). Although this report does not attempt to address mark-recapture surveys directly, illustration of the methodology employed by Gallagher (2000) is valid. Due to the types of streams surveyed, the use of boats in the surveys in this study was contingent on stream flows and depth of the water. Because the streams were relatively small and shallow, kayaks were used in this particular survey (Gallagher 2000). It was reported that this method was also employed by others in several rivers in northern California (Gallagher 2000).

5.1.1.5 Applicability to the Feather River

Due to the size of the river and the distances between potential spawning locations on the Feather River, boat surveys employing direct visual counts are a relatively broad yet informative way to obtain information regarding the location, timing, and relative abundance of steelhead spawners. The opportunity to survey the entire river reach in which spawning may occur provides an overview inventory of likely spawning locations based on the number of steelhead spawners and redds observed. However, because of disadvantages that include the elusive nature of steelhead and the difficulties associated with observing and counting steelhead in turbid waters and at high flows, boat surveys are likely most useful when combined with other, more quantitative techniques. Boat surveys provide an opportunity to cover a large river quickly looking for spawning steelhead and redds, and therefore are of value when trying to determine the reaches of a river in which steelhead spawn. Thus, boat surveys are both applicable to the Feather River and provide the type of information require to answer questions regarding steelhead spawning locations and relative abundance of steelhead spawners in the Feather River. As a result, boat surveys are recommended as a method which will contribute additional knowledge regarding the location and relative abundance of steelhead spawners in the Feather River. For the reasons discussed above, it is recommended that boat surveys be used in combination with other survey methods.

5.1.2 Video Surveys

5.1.2.1 Description

Although boat surveys utilizing direct visual counts allow surveyors to gain closer access to spawning areas and potentially to spawning individuals, direct visual methods require that fish be visible from the water surface in order to be located and counted (Bergestedt et al. 1990; Susac et al. 1999). Therefore, efficiency of these methods depends on the sampling conditions and can readily be affected by flow conditions and turbidity (Bergestedt et al. 1990). Video equipment can serve to complement direct visual observations by recording fish underwater that could have been missed by human observers above the surface. Several methods exist by which video equipment can be mounted on or towed behind a boat and used in conjunction with direct visual surveys. Towed video systems vary from single cameras with a limited angle of view to multiple camera systems aimed in different directions with different viewing angles (Bergestedt et al. 1990; Dauble et al. 1999; Groves et al. 1998; Groves et al. 1999; Nester et al. 1987).

5.1.2.2 Advantages

- Use of towed video systems is suitable in rivers and larger streams up to 13 m deep with water velocities up to 3 m/s (Groves et al. 1998).
- Use of towed video systems allows for coverage of a wide survey area (Dauble et al. 1999).
- Use of towed video systems enables surveyors to survey redds or spawning fish in deeper areas not detected by other survey methods (Groves et al. 1999).
- Use of video systems allows for improved accuracy over visual surveys alone and allows for positive species identification (Hatch et al. 1994).
- Use of video systems creates permanent records (Hatch et al. 1994; Irvine et al. 1991).
- Use of towed video systems allows for improved safety over other survey methods especially during inclement weather or high flow conditions (Dauble et al. 1999; Susac et al. 1999).
- Use of video systems can also provide qualitative information on physical habitat, such as substrate size and water turbidity (Dauble et al. 1999).

5.1.2.3 Disadvantages

- Cameras, light sources, and underwater housing equipment are expensive to buy and maintain (Dolloff et al. 1996).
- Video systems in general provide a relatively small field of view (Dauble et al. 1999).
- Video systems have a relatively limited range of lighting and turbidity conditions in which they are effective (Dauble et al. 1999).
- Towed video systems can potentially affect spawning activity by disturbing spawning fish (Groves et al. 1999).

5.1.2.4 Example applications

Towed video systems were used in multiple surveys of fall-run Chinook salmon redds on the Snake River in Idaho, Washington, and Oregon from 1993 through 1997 (Dauble et al. 1999; Groves et al. 1998; Groves et al. 1999). During this time, surveyors utilized several methods of underwater videography including towed video systems and a submersible camera attached to a hydraulic weight lowered from a boat and its depth adjusted manually (Dauble et al. 1999; Groves et al. 1999). Surveys were reportedly able to detect both spawning salmon and redds up to depths of 10 meters (Groves et al. 1999). During one of the studies, surveys were initially conducted along transects in areas where Chinook salmon were known to spawn. Upon finding suitable spawning areas, localized surveys were conducted. During the surveys, the camera was aimed at a 90° downward angle relative to the surface of the water and passed 0.6-1.3 m above the river bottom at regular intervals (e.g. 7.5-30 m apart), providing a view path of 1.5-4.2 square meters. The survey path and redd locations were mapped by using a Global Positioning Satellite (GPS) system (Dauble et al. 1999). Additionally, Groves and Garcia (1998) tested two separate types of towing mechanisms on the Snake River. Both were tested with single and multiple cameras angled either at 45º or 90º (or both when multiple cameras were tested) downward relative to the water surface. Reportedly, the use of two-camera systems allows for detection of subtle differences in substrate contrast and cross referencing, making the two-camera systems more accurate than the use of single cameras alone (Groves et al. 1998).

5.1.2.5 Applicability to the Feather River

Although video surveys may provide addition detail regarding the number of steelhead spawners and redds, because of the width and depth of the Feather River, multiple sets of multiple video cameras mounted from several boats would be required to fully document number of redds or steelhead spawners in the Feather River. Additionally, the higher winter flows and increased turbidity associated with winter conditions that make direct observation of steelhead difficult would limit the visibility of video equipment as well. Because complete coverage of the Feather River would be required to obtain complete steelhead spawner and redd estimates, it is likely that the use of towed video equipment would not be a feasible method for surveying large sections of the Feather River. While video surveys may provide better information in a focused riffle section, other survey methods such as bankside surveys may provide similar information in a less invasive and disruptive fashion. For these reasons, video surveys are not recommended at this time for use in the Feather River.

5.1.3 Snorkel surveys

5.1.3.1 Description

Snorkeling is a direct underwater observation technique that can be used to track the number of spawning steelhead in individual habitat units. Snorkeling requires the least amount of equipment of all underwater observation techniques and is one of the simplest ways to observe organisms underwater. Equipment typically includes a mask, snorkel, wet or dry suit, and swim fins or wading boots, depending on the depth and width of the river being investigated. Small streams and rivers are normally well suited for snorkel observations provided underwater visibility is adequate (Dolloff et al. 1996).

Snorkeling techniques vary depending on the study objectives and environment to be surveyed. In flowing waters, divers moving upstream are less likely to startle fish and cause them to flee or change their behavior because most stream-dwelling fish orient facing into the current. Whenever conditions permit (i.e. low flows and shallow water), divers should enter streams downstream from the unit to be sampled and proceed slowly upstream pulling themselves along the bottom being careful to avoid sudden movements. When it is impractical or too deep to move upstream, divers should enter the water upstream from the sampling unit and float downstream with the current, remaining as motionless as possible. Size and complexity of the sampled unit, underwater visibility, and the survey objectives determine the number of observers needed to complete a particular survey (Dolloff et al. 1996).

5.1.3.2 Advantages

- Snorkeling requires relatively little equipment, time and personnel (Dolloff et al. 1996; Mullner et al. 1998).
- Snorkeling equipment is relatively inexpensive (Perrow et al. 1996).
- It is relatively easy to train people to snorkel (Perrow et al. 1996).
- Snorkel surveys are not destructive and cause minimal disturbance (Mullner et al. 1998; Perrow et al. 1996).
- Snorkeling allows observation of fish interactions (Dolloff et al. 1996).
- Snorkeling can be used in remote locations where it may be difficult to use other sampling apparatus (Dolloff et al. 1996).
- Snorkeling is effective in a variety of environments and habitat types (Dolloff et al. 1996).

5.1.3.3 Disadvantages

- Diver safety is subject to weather and flow (BC Conservation Foundation 2003; Dolloff et al. 1996).
- Ability to accurately identify fish is dependent on water clarity (BC Conservation Foundation 2003; Dolloff et al. 1996).
- Steelhead are very elusive fish and can disperse while divers are far away before they are counted (BC Conservation Foundation 2003).
- Differences in fish behavior during different times of the day or year may influence observability (Rodgers et al. 1992).
- In large rivers, multiple divers are needed to estimate populations, which increases observer bias (Dolloff et al. 1996).
- Snorkeling requires certain sampling conditions in order to obtain accurate population estimates including > 30 cm depth, high underwater visibility, and a

limited amount complex cover (e.g. woody debris or interstitial spaces among the substrate) in which fish could potentially hide (Dolloff et al. 1996; Hillman et al. 1992; Mullner et al. 1998; Rodgers et al. 1992).

5.1.3.4 Example applications

Various studies have shown that direct underwater observation of spawning salmonids using snorkeling gear, either independently of in conjunction with other types of survey methods, is effective in determining spawning locations and abundance estimates (Gallagher 2000; Hillman et al. 1992; Mullner et al. 1998). In the Noyo River in California, Gallagher (2000) employed a combination of methods including snorkeling, bankside survey methods, and direct visual observations using boats to quantitatively estimate steelhead populations. The combination of methods allowed surveyors to perform studies throughout the spawning season regardless of environmental conditions.

Other studies directly evaluated the efficiency of snorkeling survey methods on several species of salmonids (Hillman et al. 1992; Mullner et al. 1998). Mullner and others (1998) reported that snorkeling counts of three species of salmonids were highly correlated with results of electrofishing survey techniques. The study was conducted by electrofishing one of 25 reaches in several small streams in the Bighorn Mountains of Wyoming immediately after completing a snorkeling survey of each reach. On average, snorkeling counts reported 65% of the number of fish collected using the electrofishing method. Because the precision of snorkeling techniques is reported to be lower than that of depletion techniques, snorkeling is suggested to be of limited value in studies attempting to estimate overall fish abundance. Under the correct conditions, however, snorkeling can be used as an alternative to depletion methods (Mullner et al. 1998).

A second study that determined the accuracy of the use of snorkeling while surveying for salmonids was conducted on two mid-Columbia River tributaries (Hillman et al. 1992). Snorkeling counts were made and compared to those made after the use of sodium cyanide in the same reaches. Hillman and others (1992) suggested that overall snorkeling efficiency in sampling juvenile salmonids was not affected by discharge, surface area, or the time of day at which the surveys were conducted, but was significantly affected by decreases in water temperature and increased cover.

5.1.3.5 Applicability to the Feather River

Snorkel surveys are applicable to the physical site conditions of Feather River because the number of snorkelers used can be adjusted, depending upon river size, in order to ensure adequate coverage of the river. However, snorkeling is not effective when conditions are turbid or flows are too high to be considered safe (DWR 2002a). Snorkel surveys provide information regarding location of spawning and relative abundance of target fish, but because of observer bias and the elusive nature of steelhead, snorkel surveys are likely not a reliable method for determining exact numbers of steelhead in the population. However, snorkel surveys provide valuable information that may be used to describe the general temporal and spatial distribution of spawning steelhead throughout the Feather River which would allow further refinement of survey areas. Because conditions are not always conducive to snorkeling (i.e., high flows, turbid water), it is recommended that snorkel surveys be utilized in combination with other survey methods.

5.1.4 Bankside surveys

5.1.4.1 Description

Bankside counts are reported to be an effective surveying technique in shallow, slow-moving, and clear waters with minimal aquatic vegetation (Perrow et al. 1996; USFWS Fairbanks Fishery Resources Office 2001). A reach to be surveyed is divided into contiguous but non-overlapping segments and surveyed systematically. Each segment of river should be small enough that all fish can be counted from a single vantage point. In general, the surveys are conducted by observers wearing polarizing sunglasses and hats to reduce glare. Pedestrian surveys are conducted by one more observers moving slowly to a vantage point from which the entire segment of the river to be surveyed can be seen and concealing themselves behind riparian vegetation or other available cover. Once in position, observers wait motionless for several minutes before beginning counting. This is done in order to minimize the effects of the disturbance created by the surveyor's approach to the bank (Perrow et al. 1996). A variation on the use of pedestrian bankside surveys is the use of counting towers (USFWS Fairbanks Fishery Resources Office 2001). In many respects, the counting tower method is similar to the pedestrian bankside survey method in that stream segments are observed from a vantage point that allows the surveyor to be somewhat concealed while still being able to observe a segment of water. Traditionally, counting towers are installed in areas through which fish migrate in order to perform migration surveys. Generally, a fence is built across part of the stream from one bank and the counting tower installed on the opposite bank. The fence forces migrating fishes to swim within view of an observer in the tower (USFWS Fairbanks Fishery Resources Office 2001). Although designed for migration surveys, the counting tower survey method can be modified for use in spawning surveys by installing towers in habitat units with high probability of spawning. Observers then have a semi-permanent vantage point from which to observe spawning activities.

5.1.4.2 Advantages (bankside surveys)

- Survey methodology is straightforward (Susac et al. 1999).
- Shore-based counts are inexpensive, fast, and easy (Perrow et al. 1996).
- Not unsafe in the winter and can be performed all throughout the spawning seasons (Susac et al. 1999).
- Stress is minimal to fish (Perrow et al. 1996).
- They are appropriate when the water is too shallow to be sampled easily by other techniques (Perrow et al. 1996).

5.1.4.3 Advantages (tower surveys)

- Counting towers can have above water or underwater video or other monitoring equipment installed (Enzenhofer et al. 1998).
- If counting towers are installed for extended periods, fish behavior is minimally affected because they become acclimated to the tower.

5.1.4.4 Disadvantages (bankside surveys and tower surveys)

- Visual counts from banks typically have high inter-observer variability thereby creating bias in the estimates (Perrow et al. 1996).
- Wide rivers or those with high flows, such as mainstem rivers, may not be able to be adequately reached or surveyed (Riggers et al. 1999).
- Fish are aware of human presence, and any disturbance will reduce the accuracy of visual estimates (Perrow et al. 1996).
- Fish can take a long time to leave cover and resume their activities following disturbance (Perrow et al. 1996).
- Counts are best made on sunny days or at least bright overcast days. Intensive sunshine can create problems with glare, and shadows can betray the presence of the observer (Perrow et al. 1996).
- Rain, wind, and surface ripples make observations nearly impossible (Perrow et al. 1996).

5.1.4.5 Example applications

Various studies have shown that bankside surveys can be used to survey for spawning and migrating salmonids (Enzenhofer et al. 1998; Gallagher 2000; Riggers et al. 1999; Straty 1960; Susac et al. 1999). Steelhead spawning surveys were conducted in 21 different watersheds or subbasins of Oregon Costal streams from mid January to mid May in 1998 utilizing various survey methods. The bankside survey portion of the study was conducted by walking upstream and surveying stream segments for live adult fish (Susac et al. 1999). The authors believed that, in conjunction with other survey methods, pedestrian bankside counts were effective in surveying for spawning steelhead (Susac et al. 1999).

Another study conducted in the Noyo River in California also suggested that pedestrian bankside surveys in conjunction with other surveys were effective in determining spawning steelhead population estimates (Gallagher 2000). Straty (1960) suggests that the use of multiple counting towers in Britsol Bay in Alaska is an effective method of enumerating migrating salmon while Enzenhofer and others (1998) used hydroacoustic and video methods along with direct visual counting to enumerate migrating salmon in the Thompson River in British Columbia (Enzenhofer et al. 1998; Straty 1960). Although neither study recommended the use of counting towers for spawning surveys, it seems logical that counting tower methodology can be used in areas where spawning potentially occurs if adequate cover for observers is unavailable. In addition, counting towers potentially provide a higher vantage point than pedestrian bankside surveys.

5.1.4.6 Applicability to the Feather River

Pedestrian bankside surveys and counting tower surveys are applicable to the physical site conditions of the Feather River when water clarity is sufficient to easily identify spawning fish and in areas where potential steelhead spawning areas are easily accessible from the bank. Because the Feather River has the potential to have high flows and turbid water during the steelhead spawning season, bankside counts might be inappropriate at certain times and therefore should not be relied upon as the sole survey methodology. Bankside surveys are most appropriate for determining the number of spawners is a particular location, and are less appropriate for determining the location or timing of steelhead spawning along the length of the Feather River. As a result, once other survey methods such as boat or snorkel surveys have been implemented and steelhead spawning areas have been relatively well-defined, bankside surveys may be appropriate to determine the number of steelhead spawners and the temporal distribution of steelhead spawners at a particular spawning location without disturbing the fish. However, in years with poor water clarity during the steelhead spawning season, bankside surveys may not be able to be conducted as a result of poor visibility associated with high flows and increased turbidity. While bankside surveys are not recommended for this field season, once spawning areas are relatively well-defined, bankside surveys could be implemented to provide more detailed counts of steelhead spawners at certain locations.

5.1.5 Stationary Underwater Time-Lapse Video

5.1.5.1 Description

Because the efficiency of visual observation of fish depends on the sampling conditions and can readily be affected by flow conditions and turbidity, videographic equipment can serve to complement visual surveys. Video recordings can be reviewed under ideal conditions to improve observer efficiency and to aid in species identification. In addition, videographic monitoring equipment can be set up in semi-permanent structures to record fish spawning while observers generally do not provide continuous monitoring. Waterproof cameras may be placed in camouflaged areas in fixed locations and remotely operated to take pictures continuously or at predetermined frequencies (time-lapse videography). Remote cameras and lighting systems allow investigators to obtain information on populations of organisms at any time of the day or night (Dolloff et al. 1996).

5.1.5.2 Advantages

- Semi-permanent structures with video equipment allows for uninterrupted monitoring of an area (Grant et al. 2002).
- Cameras that are left in the water for extended periods provide views of undisturbed behavior (Bonneville Power Administration 2003).

- Long-term monitoring can be conducted using multiple video recorders timed to record in sequence (Bonneville Power Administration 2003).
- Videography creates permanent records that are subject to a variety of analyses (Hatch et al. 1994; Irvine et al. 1991).
- Very little labor is required once recording stations have been installed (i.e., many stations can be operated by one individual) (Newcomb et al. 1997).
- Video provides improved accuracy over visual surveys alone (Hatch et al. 1994).
- Videographic records allow for confirmation of data collected in the field including accurate species identification in areas where multiple salmonid species are present (Hatch et al. 1994).

5.1.5.3 Disadvantages

- Cameras, light sources, underwater housing, and remote sensing equipment are expensive to buy and maintain (Dolloff et al. 1996).
- Divers are generally required to install and service equipment on a periodic basis (Dolloff et al. 1996).
- Remote cameras are limited by the some of the same conditions affecting underwater observers such as low-light or turbid water (Dolloff et al. 1996).
- If video equipment is used at night, light sources could potentially disturb fish and alter behavior or disrupt spawning activity (Grant et al. 2002).
- Stationary equipment is subject to theft and vandalism.

5.1.5.4 Example applications

Studies have shown that stationary underwater video equipment can be successfully used to monitor spawning and migrating salmonids (Grant et al. 2002; Hatch et al. 1994). In a study at the Tumwater Dam on the Wenatchee River in Washington, three species of migrating salmonids (Chinook salmon, sockeye salmon and steelhead) were successfully monitored using stationary time-lapse videography. During the study, fish were videotaped using the fish ladder as they attempted to migrate upstream. The study showed that video-based escapement estimates were within four percent of on-site visual estimates (Hatch et al. 1994). A second study illustrates the use of time-lapse videography on spawning brown and brook trout in Valley Creek in Minnesota. During the survey, twelve redds were continuously monitored for 24 h with underwater video cameras using time-lapse videography (Grant et al. 2002). Although the study was designed to assess the behavior of sympatric trout species rather than determine the number and location of spawning fish in an area, it illustrates the use of time-lapse videograhpy in spawning surveys.

5.1.5.5 Applicability to the Feather River

The use of stationary underwater time-lapse video in conducting spawning surveys is applicable to the physical site conditions on the Feather River when water clarity is sufficient to provide discernable video images of spawning fish. Because the Feather River has the potential to have high flows and turbid water during the steelhead spawning season, stationary time-lapse video surveys may be ineffective at certain times and therefore should not be relied upon as the sole survey methodology. Once other survey methods such as boat or snorkel surveys have been implemented and steelhead spawning areas have been relatively well-defined, stationary time-lapse video surveys may provide useful supplementary survey data without disturbing the fish. Stationary underwater time-lapse video surveys may provide addition detail regarding the number of steelhead spawners, spawning behavior, and temporal distribution of spawners at a very specific spawning locations, but because of the width and depth of the Feather River, several stationary time-lapse video cameras would be required to cover the entire width of the Feather River at a single spawning riffle location. Additionally, in years with poor water clarity during the steelhead spawning season, stationary time-lapse video surveys may not yield high-quality images as a result of poor visibility associated with high flows and increased turbidity. While stationary-time lapse video surveys are not recommended for this field season, once spawning areas are relatively well-defined, these surveys could be implemented to provide more detailed information describing the number of spawners, spawner behavior, and the temporal distribution of steelhead spawners at specific locations.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The results of the literature review on potential survey methods for observing spawning steelhead reveal that a combination of methods is best suited for use on the Feather River. Visual boat surveys are recommended for this field season as a method to obtain information regarding the location, timing, and relative abundance of steelhead spawners in the Feather River. Boat surveys are recommended because they provide the opportunity to survey the entire reach of interest in the lower Feather River quickly, while collecting data that may be useful in determining specific spawning areas that may be surveyed by other survey methods. Additionally, snorkel surveys are recommended for this field season for similar reasons. The combination of snorkel surveys and boat surveys will facilitate obtaining an inventory of steelhead spawning locations in the Feather River. Once survey methods such as boat surveys and snorkel surveys have been implemented and steelhead spawning areas are relatively well-defined, bankside surveys and stationary time-lapse video surveys may be useful in obtaining additional information at specific redd locations, such as the number of steelhead spawners, spawning behavior, and the temporal distribution of spawners, if such additional detail is needed. All of the survey methods reviewed are subject to the difficulties associated with the elusive nature of steelhead and the high turbidity and high flow conditions that may occur during the steelhead spawning season. As a result, at times of high turbidity and high flow conditions during the steelhead spawning season, the surveys methods reviewed may not be safe to implement or may produce results of relatively limited utility. These conclusions and recommendations confirm the results of the preliminary steelhead spawning survey methodology research conducted in the study plan development and in the definition of the steelhead spawning survey associated with Task 2B of SP-F10.

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